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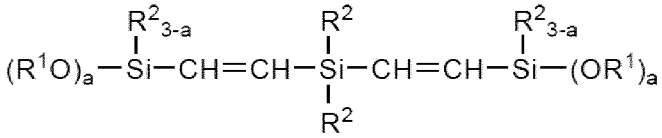
(54) NOVEL BIS (ALKOXYSILYL-VINYLENE) GROUP-CONTAINING SILICON COMPOUND AND MANUFACTURING METHOD THEREFOR

(57) Provided is an organic silicon compound represented by the following general formula (1)

[Chemical formula 1]



(1)

(wherein R^1 represents either an alkyl group that has 1 to 20 carbon atoms and may have a substituted group or a cycloalkyl group that has 3 to 20 carbon atoms and may have a substituted group; R^2 represents either a hydrogen atom or a monovalent hydrocarbon group that has 1 to 20 carbon atoms and may have a substituted group, and R^2 may be either identical or different; and each a independently represents an integer of 1 to 3).

The novel silicon-containing compound of the present invention provides a cured product of a room temperature-curable organopolysiloxane composition that is particularly superior in fast curability.

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Description

TECHNICAL FIELD

[0001] The present invention relates to a novel organic silicon compound, especially a novel organic silicon compound useful as a curing agent with an effect of imparting a superior fast curability to a room temperature-curable organopolysiloxane composition; and a production method thereof. In each molecule of such organic silicon compound, provided on an identical silicon atom are two sets of: a hydrolyzable silyl group such as an alkoxysilyl group; and a structure where two silicon atoms are bonded to each other through a carbon-carbon double bond (i.e. silyl-vinylene structure or silyl-ethenylene structure).

BACKGROUND ART

[0002] Conventionally, there have been known various types of room temperature-curable compositions capable of being cured into elastomer-like products at room temperature by coming into contact with the moisture in the air. Particularly, those releasing alcohols as they cure are characterized in that they do not produce unpleasant odors and corrode metals, which is why such a type of room temperature-curable compositions have been preferably used in performing sealing, bonding and coating in, for example, electric and electronic equipments.

[0003] Typical examples of the above type of room temperature-curable composition include a composition composed of a hydroxyl group-terminated polyorganosiloxane, alkoxysilane and an organic titanium compound; a composition composed of an alkoxysilyl group-terminated polyorganosiloxane, alkoxysilane and alkoxy titanium; a composition composed of a linear polyorganosiloxane containing a silethylene group(s) and terminated by alkoxysilyl groups, alkoxysilane and alkoxy titanium; and a composition composed of a hydroxyl group-terminated polyorganosiloxane or an alkoxy group-terminated polyorganosiloxane and an alkoxy-α-silylester compound (Patent documents 1 to 4).

[0004] Although these compositions exhibit a storage stability, a water resistance and a moisture resistance to a certain degree, these properties are not yet completely satisfactory. Further, these compositions have so far exhibited an insufficient fast curability.

[0005] As described above, polymers having reactive alkoxysilyl groups on their terminal ends are known. Since these polymers have their polymer terminal ends blocked by alkoxysilyl groups from the beginning, the curability of a composition containing the same is less likely to change (deteriorate) with time, and a superior storage stability can thus be achieved. Further, a workability (viscosity, thixotropy) of such composition can be arbitrarily controlled, and superior properties (hardness, tensile strength and elongation at break) can also be achieved as those polymers form elastomers through reactions with the moisture in the air and then through cross-liking reactions.

[0006] However, those of dealcoholization type have exhibited an insufficient curability, since they are less reactive with the moisture in the air as compared to those of other known curing types such as deoximation type, de-acetic acid type and deacetone type.

[0007] Here, while developments have been made on a room temperature-curable polyorganosiloxane composition superior in fast curability and capable of forming a cured product superior in moisture resistance, those that can be industrially advantageously produced have not yet been found.

PRIOR ART DOCUMENT

Patent Document

[0008]

Patent document 1: Japanese Examined Patent Publication No. Sho 39-27643
Patent document 2: JP-A-Sho 55-43119
Patent document 3: Japanese Examined Patent Publication No. Hei 7-39547
Patent document 4: JP-A-Hei 7-331076
Patent document 5: Japanese Unexamined Patent Application Publication (Translation of PCT Application) No. 2012-511607

SUMMARY OF THE INVENTION

Problem to be solved by the invention

[0009] The present invention was made in view of the above issues, and it is an object of the present invention to

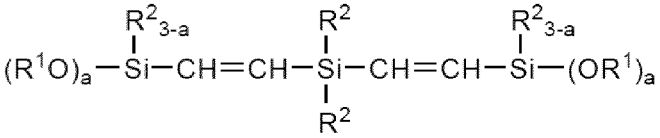
provide a curing agent for a room temperature-curable organopolysiloxane composition. The curing agent is especially capable of imparting a fast curability to the room temperature-curable organopolysiloxane composition, and can thus provide a cured product superior in storage stability and durability. Further, the room temperature-curable organopolysiloxane composition can be industrially advantageously produced using a highly general material(s).

Means to solve the problem

[0010] The inventors of the present invention diligently conducted a series of studies and completed the invention as follows. That is, the inventors found that the hydrolyzability of an alkoxy group in an alkoxysilyl group could be dramatically improved, only when a linking group adjacent to such alkoxysilyl group was a vinylene group (ethenylene group). Specifically, the inventors found that by using a compound that is represented by the following formula (1) and contains alkoxysilyl-vinylene groups, there could be obtained a room temperature-curable composition especially superior in fast curability and capable of forming a cured product with a favorable storage stability and durability. More specifically, the inventors were able to arrive at a room temperature-curable organopolysiloxane composition that can be industrially advantageously produced due to the fact that a highly general material(s) (e.g. diorgano dichlorosilane) can be used as a part of a starting material(s) for producing the above alkoxysilyl-vinylene group-containing compound.

<1> That is, the present invention is to provide an organic silicon compound represented by the following general formula (1)

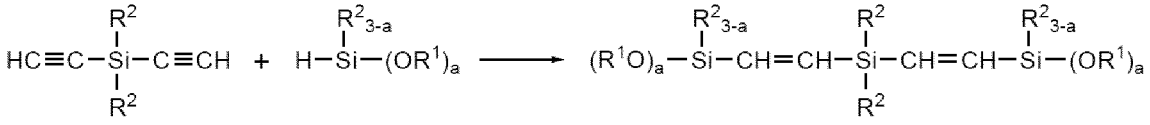
[Chemical formula 1]



(1)

(wherein R^1 represents either an alkyl group that has 1 to 20 carbon atoms and may have a substituted group or a cycloalkyl group that has 3 to 20 carbon atoms and may have a substituted group; R^2 represents either a hydrogen atom or a monovalent hydrocarbon group that has 1 to 20 carbon atoms and may have a substituted group, and R^2 may be either identical or different; and each a independently represents an integer of 1 to 3). Here, in the present invention, ethenylene group represented by -CH=CH- may be referred to as vinylene group or the like hereunder.
<2> Further, the present invention provides a production method of the organic silicon compound as set forth in <1>, comprising adding two hydrogenalkoxysilanes (3) to one silane compound (2) having two ethynyl groups on an identical silicon atom, through a hydrosilylation addition reaction

[Chemical formula 2]



(2) (3) (1)

(wherein R^1 represents either an alkyl group that has 1 to 20 carbon atoms and may have a substituted group or a cycloalkyl group that has 3 to 20 carbon atoms and may have a substituted group; R^2 represents either a hydrogen atom or a monovalent hydrocarbon group that has 1 to 20 carbon atoms and may have a substituted group, and R^2 may be either identical or different; and each a independently represents an integer of 1 to 3).

Effects of the invention

[0011] The novel silicon-containing compound of the present invention provides a cured product superior in fast curability, and allows a composition using the same to be quickly cured when exposed to the air even after the composition had been stored for 12 months. Here, a cured product thus obtained exhibits superior properties. Therefore, a composition having, as a curing agent, the novel silicon-containing compound of the present invention (e.g. room temperature-curable organopolysiloxane composition) is useful as a sealing agent, coating material or adhesive agent for use in certain

locations where heat resistance, water resistance and moisture resistance are required. Particularly, such composition can be effectively used for construction purposes and applied to an adhesive agent for electric and electronic parts, where steam resistance and water resistance are required. Further, since the silicon-containing compound of the present invention uses a general-purpose chlorosilane, it can be easily industrialized.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

FIG.1 is a diagram showing a ^{1}H-NMR spectrum of a reaction product ([bis (trimethoxysilyl-vinylene) dimethylsilane]) in a synthesis example 1.
FIG.2 is a diagram showing a ^{1}H-NMR spectrum of a reaction product ([bis (trimethoxysilyl-vinylene) diphenylsilane]) in a synthesis example 2.

MODE FOR CARRYING OUT THE INVENTION

[0013] The present invention is described in greater detail hereunder.

< Silicon-containing compound terminated by alkoxysilyl-vinylene group >

[0014] The silicon-containing compound terminated by alkoxysilyl-vinylene group which is represented by the above general formula (1) is that having not less than two alkoxysilyl-vinylene bonds on an identical silicon atom (i.e. bis (alkoxysilyl-vinylene) silane compound).

[0015] Here, in the above general formula (1), examples of R^1 as an alkyl group having 1 to 20 carbon atoms include a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a tert-butyl group, a pentyl group, a neopentyl group, a hexyl group, a heptyl group, an octyl group, a nonyl group, a decyl group, an undecyl group, a dodecyl group, a tridecyl group, a tetradecyl group, a pentadecyl group, a hexadecyl group, a heptadecyl group, an octadecyl group, a nonadecyl group and an eicosyl group. Examples of a cycloalkyl group include a cyclopentyl group and a cyclohexyl group. Examples of an alkyl group that has 1 to 20 carbon atoms and may have a substituted group(s), include an aralkyl group such as a benzyl group, a 2-phenylethyl group and a 3-phenylpropyl group. Further, all or a part of the hydrogen atoms in any of these (substituted) alkyl groups may be substituted by, for example, cyano groups and/or halogen atoms such as F, Cl and Br. Examples of a substituted group thus obtained include a 3-chloropropyl group, a 3,3,3-trifluoropropyl group and a 2-cyanoethyl group. Among all the above examples, preferred as R^1 are alkyl groups having 1 to 6, particularly 1 to 4 carbon atoms. A methyl group and an ethyl group are more preferred as R^1, where a methyl group is even more preferred in terms of availability, productivity and cost.

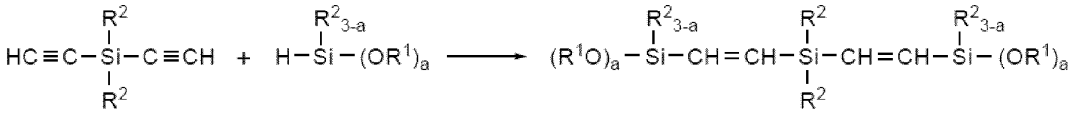
[0016] R^2 represents a substituted or unsubstituted monovalent hydrocarbon group having 1 to 20 carbon atoms. R^2s may be identical to or different from one another. Examples of such R^2 include an alkyl group such as a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a tert-butyl group, a pentyl group, a neopentyl group, a hexyl group, a heptyl group, an octyl group, a nonyl group, a decyl group, a undecyl group, a dodecyl group, a tridecyl group, a tetradecyl group, a pentadecyl group, a hexadecyl group, a heptadecyl group, an octadecyl group, a nonadecyl group and an eicosyl group; a cycloalkyl group such as a cyclopentyl group and a cyclohexyl group; an alkenyl group such as a vinyl group, an allyl group, a butenyl group, a pentenyl group and a hexenyl group; an aryl group such as a phenyl group, a tolyl group, a xylyl group and an α-, β-naphthyl group; and an aralkyl group such as a benzyl group, a 2-phenylethyl group and a 3-phenylpropyl group. R^2 may also be a group obtained by substituting a part of or all the hydrogen atoms in any of these groups with, for example, cyano groups and/or halogen atoms such as F, Cl and Br. Examples of such substituted group include a 3-chloropropyl group, 3,3,3-trifluoropropyl group and a 2-cyanoethyl group. Among all the above examples, preferred are monovalent hydrocarbon groups having 1 to 10, particularly 1 to 6 carbon atoms. A methyl group, an ethyl group and a phenyl group are more preferred, where a methyl group and a phenyl group are even more preferred in terms of availability, productivity and cost. Each a independently represents an integer of 1 to 3. However, it is preferred that a be either 2 or 3, more preferably 3.

[0017] The organic silicon compound represented by the general formula (1) of the present invention is mainly used as a curing agent for a (room temperature) curable composition. Particularly, those having three methoxy groups on an identical silicon atom in a molecule (six in total per molecule) contain a trifunctional alkoxysilane site(s), and are thus useful as curing agents (cross-linking agent) for a dealcoholized silicone RTV (room temperature-curable organopolysiloxane composition).

< Production method of organic silicon compound represented by general formula (1) >

[0018] The silicon-containing compound of the invention which has two alkoxysilyl-vinylene bonds on an identical silicon atom can, for example, be easily produced through an addition reaction such as a hydrosilylation reaction between a silane having two ethynyl groups on an identical silicon atom and two alkoxysilanes (hydrogenalkoxysilane). This reaction is expressed by the following formula [1].

[Chemical formula 3]



[1]

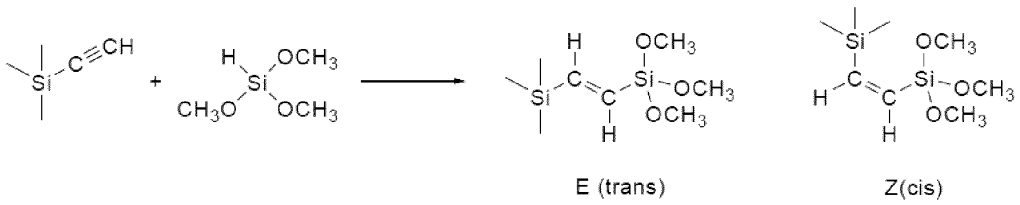
(In the above formula, R^1, R^2 and a are defined as above.)

[0019] As an addition reaction catalyst used when adding alkoxysilane (hydrogenalkoxysilane), platinum group metal-based catalysts such as a platinum-based catalyst, a palladium-based catalyst, a rhodium-based catalyst and a ruthenium-based catalyst are available. Here, a platinum-based catalyst is particularly preferred. Examples of such platinum-based catalyst include a platinum black; a catalyst with a solid platinum being supported on a support such as alumina and silica; a chloroplatinic acid; an alcohol-modified chloroplatinic acid; a complex of a chloroplatinic acid and olefin; and a complex of platinum and vinylsiloxane. These kinds of platinum may be used in a so-called catalytic amount, and may, for example, be used in an amount of 0.1 to 1,000 ppm, particularly 0.5 to 100 ppm in terms of platinum group metal, with respect to alkoxysilanes.

[0020] It is desired that this reaction be performed at a temperature of 50 to 120°C, particularly 60 to 100°C, for 0.5 to 12 hours, particularly 1 to 6 hours, and the reaction can be performed without a solvent. However, an appropriate solvent such as toluene and xylene may be used, provided that no adverse impact will be inflicted upon the above addition reaction or the like.

[0021] In an addition reaction to silyl-acetylene group (silyl-ethynyl group), a geometric isomer represented by the following reaction formula [2] will, for example, be produced. In such geometric isomer, the production of E isomer (trans isomer) is highly selective and highly reactive. Since there will be no adverse impact on the properties of the silicon-containing compound of the present invention, these geometric isomers need not be separated at the time of use.

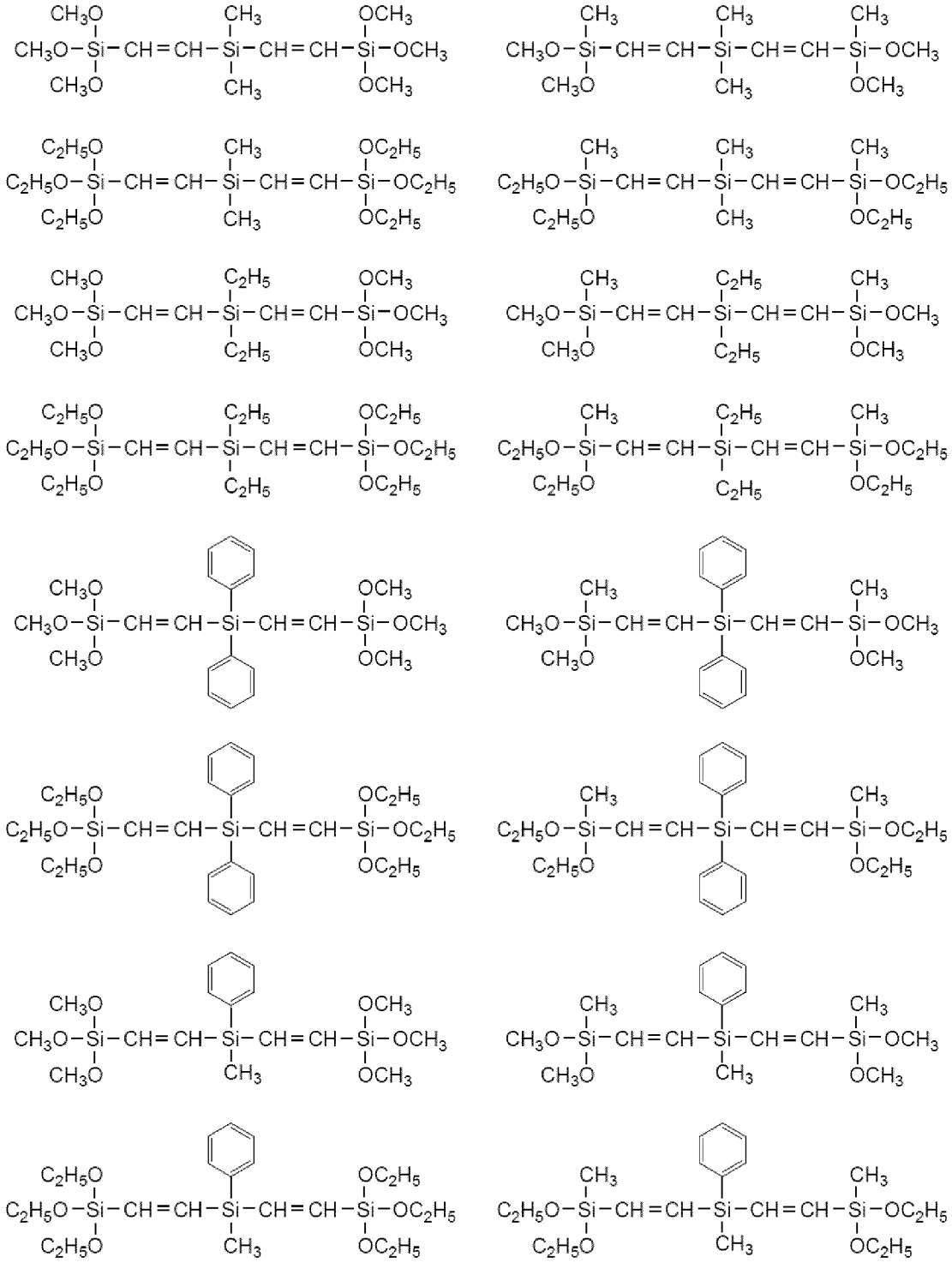
[Chemical formula 4]



[2]

[0022] Specific examples of the organic silicon compound represented by the general formula (1) of the invention include those represented by the following structural formulae.

[Chemical formula 5]



WORKING EXAMPLE

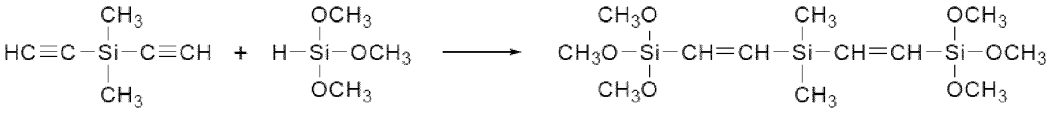
[0023] The present invention is described in detail hereunder with reference to working examples (synthesis examples), reference examples and comparative reference examples. However, the present invention is not limited to the following working examples. Further, in the specific examples below, "part" refers to "part by mass," and viscosity refers to a value measured by a rotary viscometer at 25°C.

[Working example 1]

< Synthesis of silicon-containing compound having two alkoxysilyl-vinylene groups on an identical silicon atom-[bis (trimethoxysilyl-vinylene) dimethylsilane] >

[0024] Diethynyldimethylsilane of 35.0 g (0.323 mol), a 0.5 wt% toluene solution of a chloroplatinic acid ($H_2PtCl_6 \cdot 6H_2O$) of 0.10g and toluene of 50 mL were put into a 500 mL four-necked separable flask equipped with a mechanical stirrer, a thermometer and a dropping funnel, followed by delivering thereinto 83.01 g (0.678 mol) of trimethoxysilane by drops. Later, stirring was performed at 85°C for 6 hours, followed by performing distillation so as to obtain 106.2 g (yield 90%) of a silicon compound [bis (trimethoxysilyl-ethylene) dimethylsilane] shown below. Next, a ^{1}HNMR chart of this silicon compound was analyzed, and it was confirmed that the silicon compound was the target bis (trimethoxysilyl-vinylene) dimethylsilane (trans : cis = 8 : 1) (compound shown below). This reaction is shown in the following formula [3].

[Chemical formula 6]



[3]

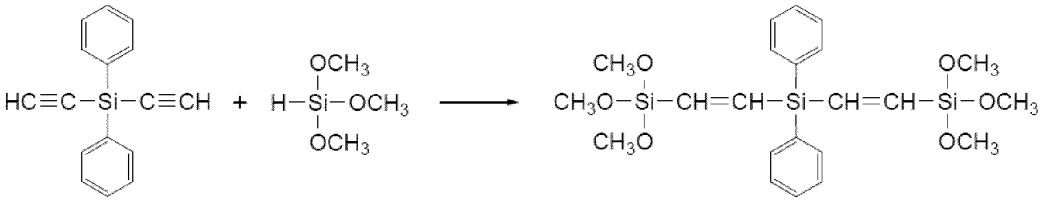
[0025] The ^{1}H-NMR spectrum data of this compound are as follows.
^{1}H-NMR (400 MHz, C_6D_6, δ (ppm)):0.00 (s, 6H), 3.36 (s, 18H), 6.47 (d, 2H), 7.10 (d, 2H)

[Working example 2]

< Synthesis of silicon-containing compound having two alkoxysilyl-vinylene groups on an identical silicon atom-[bis (trimethoxysilyl-vinylene) diphenyl silane] >

[0026] Diethynyldiphenylsilane of 34.9 g (0.151 mol), a 0.5 wt% toluene solution of a chloroplatinic acid ($H_2PtCl_6 \cdot 6H_2O$) of 0.10 g and toluene of 50 mL were put into a 500 mL four-necked separable flask equipped with a mechanical stirrer, a thermometer and a dropping funnel, followed by delivering thereinto 38.5 g (0.315 mol) of trimethoxysilane by drops. Later, stirring was performed at 85°C for 6 hours, followed by performing distillation so as to obtain 56.5 g (yield 88%) of a silicon compound [bis (trimethoxysilyl-ethylene) diphenylsilane] shown below. Next, a ^{1}HNMR chart of this silicon compound was analyzed, and it was confirmed that the silicon compound was the target bis (trimethoxysilyl-vinylene) diphenylsilane (trans : cis = 9 : 1) (compound shown below). This reaction is shown in the following formula [4].

[Chemical formula 7]



[4]

[0027] The ^{1}H-NMR spectrum data of this compound are as follows.
^{1}H-NMR (400 MHz, C_6D_6, δ (ppm)): 3.61 (s, 18H), 6.45 (d, 2H), 7.31 (d, 2H), 7.36-7.55 (m, 10H),

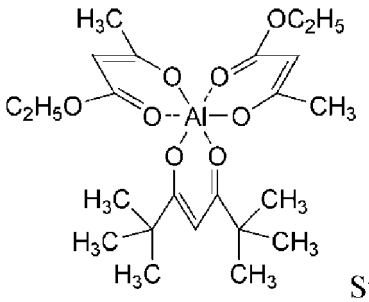
[Reference example 1]

[0028] Combined were 100 parts of a dimethylpolysiloxane having a viscosity of 5,000 mPa·s, and a molecular chain whose two ends are blocked by hydroxyl groups (or hydroxydimethylsiloxy groups); 4.9 parts of bis (trimethoxysilyl-vinylene) dimethylsilane; and 0.75 parts of tetramethylguanidylpropyltrimethoxysilane, followed by keeping mixing them under a moisture-blocked condition until a uniform level had been reached, thus obtaining a composition.

[Reference example 2]

[0029] Combined were 100 parts of a dimethylpolysiloxane having a viscosity of 5,000 mPa·s, and a molecular chain whose two ends are blocked by hydroxyl groups (or hydroxydimethylsiloxy groups); 4.9 parts of bis (trimethoxysilyl-vinylene) dimethylsilane; and 1.0 part of an organic aluminum compound which was a mono (dipivaloylmethane) aluminum bis (ethylacetoacetate) chelate having an average structure represented by the following structural formula (2), followed by keeping mixing them under a moisture-blocked condition until a uniform level had been reached, thus obtaining a composition.

[Chemical formula 8]

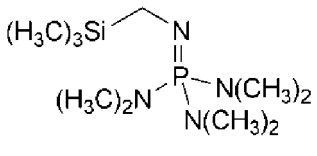


Structural formula (2)

[Reference example 3]

[0030] Combined were 100 parts of a dimethylpolysiloxane having a viscosity of 5,000 mPa·s, and a molecular chain whose two ends are blocked by hydroxyl groups (or hydroxydimethylsiloxy groups); 4.9 parts of bis (trimethoxysilyl-vinylene) dimethylsilane; and 0.2 parts of a compound which was an N,N,N',N',N",N"-hexamethyl-N"'-(trimethylsilylmethyl)- phosphorimidic triamide represented by the following structural formula (3), followed by keeping mixing them under a moisture-blocked condition until a uniform level had been reached, thus obtaining a composition.

[Chemical formula 9]



Structural formula (3)

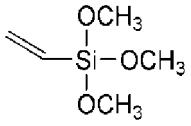
[Reference example 4]

[0031] A composition was obtained in the similar manner as reference example 1, except that 6.6 parts of bis (trimethoxysilyl-ethylene) diphenylsilane was used instead of bis (trimethoxysilyl-vinylene) dimethylsilane.

[Comparative reference examples 1 to 3]

[0032] Compositions were obtained in the similar manners as reference examples 1 to 3, except that there were used 4.1 parts of a silicon compound (vinyltrimethoxysilane) represented by the following structural formula (4) instead of bis (trimethoxysilyl-vinylene) dimethylsilane.

[Chemical formula 10]

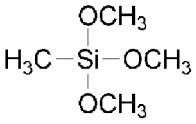


Structural formula (4)

[Comparative reference examples 4 to 6]

[0033] Compositions were obtained in the similar manners as reference examples 1 to 3, except that there were used 3.8 parts of a silicon compound (methyltrimethoxysilane) represented by the following structural formula (5) instead of bis (trimethoxysilyl-vinylene) dimethylsilane.

[Chemical formula 11]

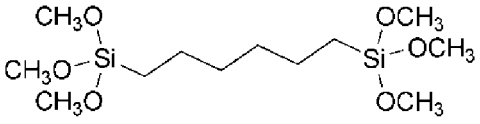


Structural formula (5)

[Comparative reference example 7]

[0034] A composition was obtained in the similar manner as reference example 1, except that there were used 4.5 parts of a silicon compound (1,6-bis (trimethoxysilyl) hexane) represented by the following structural formula (6) instead of bis (trimethoxysilyl-vinylene) dimethylsilane.

[Chemical formula 12]



Structural formula (6)

[Measurement of tack-free time]

[0035] There was measured a tack-free time of each of the compositions obtained in reference examples 1 to 4; and comparative reference examples 1 to 7.

[0036] In addition, each of the compositions obtained in reference examples 1 to 4; and comparative reference examples 1 to 7 was pushed out into a sheet-like shape of a thickness of 2 mm, immediately after they had been produced. The sheet-shaped composition was then exposed to an air of 23±2°C, 50±5% RH, and left under the same atmosphere for three days so as to obtain a cured product whose properties (initial properties) were then measured in accordance with JIS K-6249. Here, a hardness was measured by a hardness meter which was an A-type durometer described in JIS K-6249.

[0037] Further, similar measurements were performed on a product obtained by storing the above cured product in a thermo-hygrostat of 85°C, 85% RH for 7 days. Furthermore, similar measurements were also performed on a product obtained by heating the above cured product in an oven of 150°C for 10 days.

[0038] Table 1 shows the results of reference examples 1 and 4; and comparative reference examples 1, 4 and 7. Table 2 shows the results of reference example 2; and comparative reference examples 2 and 5. Table 3 shows the results of reference example 3; and comparative reference examples 3 and 6.

[Table 1]

Measurement result		Reference Example 1	Reference Example 4	Comparative Reference Example 1	Comparative Reference Example 4	Comparative Reference Example 7
Tack-free time (min)		5	3	60<	60<	60<
Initial RTV 7 days	Hardness (Durometer A)	22	25	16	6	24
	Elongation (%)	105	130	110	235	0.33
	Tensile strength (MPa)	0.45	0.52	0.27	0.19	100
Moisture resistance 85°C/85%RH 7 days	Hardness (Durometer A)	10	16	4	1	8
	Elongation (%)	155	165	430	365	120
	Tensile strength (MPa)	0.25	0.27	0.22	0.08	0.15
Heat resistance 150°C 10 days	Hardness (Durometer A)	20	20	15	12	23
	Elongation (%)	140	130	105	100	120
	Tensile strength (MPa)	0.47	0.35	0.23	0.22	0.29

[Table 2]

Measurement result		Reference Example 2	Comparative Reference Example 2	Comparative Reference Example 5
Tack-free time (min)		2	10	15<
Initial RTV 7 days	Hardness (Durometer A)	12	4	0
	Elongation (%)	105	210	430
	Tensile strength (MPa)	0.27	0.15	0.13
Moisture resistance 85°C/85%RH 7 days	Hardness (Durometer A)	11	0.5	0
	Elongation (%)	150	375	530
	Tensile strength (MPa)	0.33	0.16	0.13

(continued)

Measurement result		Reference Example 2	Comparative Reference Example 2	Comparative Reference Example 5
Heat resistance 150°C 10 days	Hardness (Durometer A)	18	15	14
	Elongation (%)	125	190	215
	Tensile strength (MPa)	0.45	0.38	0.38

[Table 3]

Measurement result		Reference Example 3	Comparative Reference Example 3	Comparative Reference Example 6
Tack-free time (min)		4	60<	60<
Initial RTV 7 days	Hardness (Durometer A)	25	16	8
	Elongation (%)	100	105	215
	Tensile strength (MPa)	0.46	0.29	0.22
Moisture resistance 85°C/85%RH 7 days	Hardness (Durometer A)	15	10	6
	Elongation (%)	135	165	260
	Tensile strength (MPa)	0.33	0.26	0.25
Heat resistance 150°C 10 days	Hardness (Durometer A)	26	18	10
	Elongation (%)	115	135	100
	Tensile strength (MPa)	0.51	0.31	0.16

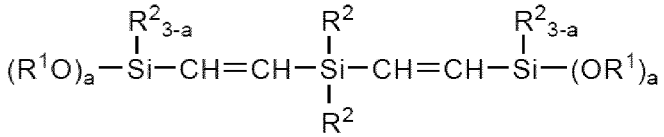
[0039] As described above, the organic silicon compound of the present invention provides a cured product superior in fast curability and durability, and can thus serve as a curing agent component effective for a room temperature-curable organopolysiloxane composition.

[0040] However, the present invention is not limited to the above embodiment. The above embodiment is simply an example; and any embodiment belongs to the technical scope of the present invention, if the embodiment has a composition substantially identical to that of the technical ideas described in the claims of the invention, and brings about the similar function effects.

Claims

1. An organic silicon compound (A) represented by the following general formula (1)

[Chemical formula 1]

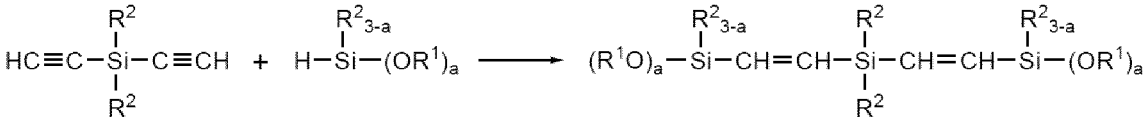


(1)

(wherein R^1 represents either an alkyl group that has 1 to 20 carbon atoms and may have a substituted group or a cycloalkyl group that has 3 to 20 carbon atoms and may have a substituted group; R^2 represents either a hydrogen atom or a monovalent hydrocarbon group that has 1 to 20 carbon atoms and may have a substituted group, and R^2 may be either identical or different; and each a independently represents an integer of 1 to 3).

2. A production method of the organic silicon compound as set forth in claim 1, comprising adding two hydrogenalkoxysilanes (3) to one silane compound (2) having two ethynyl groups on an identical silicon atom, through a hydrosilylation addition reaction

[Chemical formula 2]



(2) (3) (1)

(wherein R^1 represents either an alkyl group that has 1 to 20 carbon atoms and may have a substituted group or a cycloalkyl group that has 3 to 20 carbon atoms and may have a substituted group; R^2 represents either a hydrogen atom or a monovalent hydrocarbon group that has 1 to 20 carbon atoms and may have a substituted group, and R^2 may be either identical or different; and each a independently represents an integer of 1 to 3).

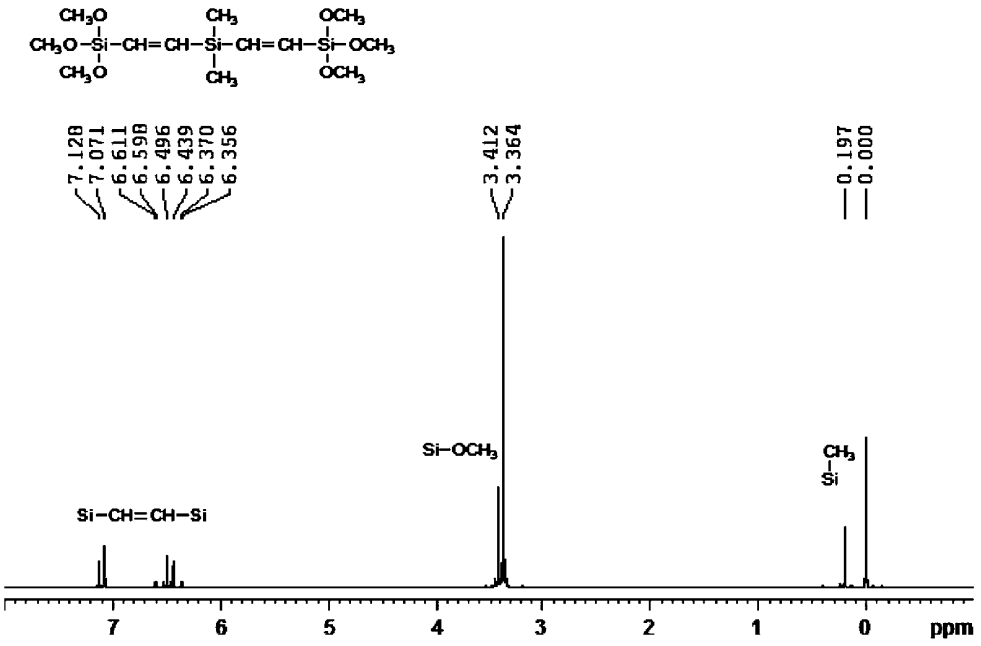

7.128
7.071
6.611
6.598
6.496
6.439
6.370
6.356
3.412
3.364
0.197
0.000
Si-OCH3
Si-CH=CH-Si
CH3
Si
7
6
5
4
3
2
1
0
ppm

FIG.1

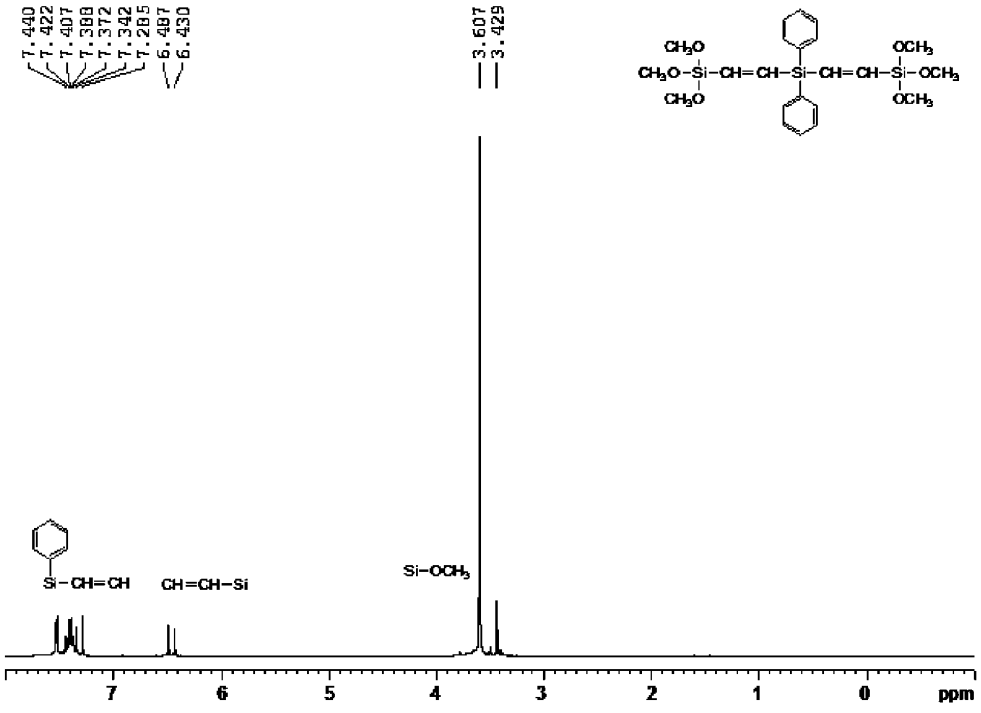

7.440
7.422
7.407
7.388
7.372
7.342
7.285
6.487
6.430
3.607
3.429
Si-CH=CH
CH=CH-Si
Si-OCH3
7
6
5
4
3
2
1
0
ppm

FIG.2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/052809

A. CLASSIFICATION OF SUBJECT MATTER
C07F7/18(2006.01)i, *C07B61/00*(2006.01)n

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C07F7/18, C07B61/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2015
Kokai Jitsuyo Shinan Koho 1971-2015 Toroku Jitsuyo Shinan Koho 1994-2015

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
CAplus(STN), REGISTRY(STN)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	VORONKOV, M. G. et al., Reaction of bis[β-(methyldimethoxysilyl)vinyl]dimethylsilanes and bis[β-(methyldimethoxysilyl)vinyl] methylmethoxysilanes with methylmagnesium iodide, Zhurnal Obshchei Khimii, 1977, Vol.47, No.4, p.960	1 2
X Y	VORONKOV, M. G. et al., Derivatives of methyl substituted trans-1,2-disilylethylene, Izvestiya Akademii Nauk SSSR, Seriya Khimicheskaya, 1974, No.9, p.2066-70	1,2 2

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 March 2015 (30.03.15)	07 April 2015 (07.04.15)
Name and mailing address of the ISA/ Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP SHO3927643 B **[0008]**
- JP SHO5543119 A **[0008]**
- JP HEI739547 B **[0008]**
- JP HEI7331076 A **[0008]**
- JP 2012511607 W **[0008]**